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INTERACTIVE ANALYSIS PROGRAM ACTIVITY

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OVERVIEW

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INTERACTIVE ANALYSIS PROGRAM ACTIVITY

In order to produce meaningful, alternative large space structure preliminary configurations, designers must have highly flexible and efficient computer codes to evaluate critical interactive effects. These interactive effects arise from the varied parameters of physical plant performance, environments, and forcing functions associated with disciplines such as thermal, structures, and controls. Adverse effects can be expected to significantly impact system design aspects such as loads, structural integrity, controllability, and mission performance. The end product analysis system is conceived to be an integration of individual discipline computer codes into a highly user oriented/interactive graphics based analysis capability. This integration of computer codes must be done in a manner that will greatly accelerate interdisciplinary data flow by maximizing use of modern data base management techniques. By providing computer assisted interdisciplinary preliminary design analysis capability, the designer will be afforded a rapid and efficient system to minimize solution turnaround time.

INTERACTIVE ANALYSIS PROGRAM ACTIVITY

o OVERALL OBJECTIVE

PRODUCE AN ANALYSIS SOFTWARE SYSTEM CAPABLE OF PERFORMING INTERDISCIPLINARY PRELIMINARY DESIGN ANALYSES OF LARGE SPACE SYSTEMS. DISCIPLINES SUCH AS THERMAL, STRUCTURES, AND CONTROLS ARE TO BE INTEGRATED INTO A HIGHLY USER ORIENTED ANALYSIS CAPABILITY. THE KEY FEATURE OF THE INTEGRATED ANALYSIS CAPABILITY IS TO BE A RAPID AND EFFICIENT SYSTEM THAT WILL MINIMIZE SOLUTION TURNAROUND TIME.

o SPECIFIC GOAL

HAVE OPERATIONAL INTEGRATED ANALYSIS CAPABILITY (IAC) FUNCTIONING BY END OF FY83

INTERACTIVE ANALYSIS PROGRAM ACTIVITY

In FY79 there was both in-house (GSFC) and contractor activities (Boeing Aerospace Co.). The in-house activities centered around tasks that will provide technical information/analysis techniques to feed into the major contractor activity. In the thermal and structural discipline areas, there is the critical need to identify the individual analysis codes that best match the requirements imposed by an integrated analysis system. In addition, a somewhat new approach to thermal analysis, based on the modal solution techniques, is to be assessed for practical usage. Since no general technique existed for the linearization of sampled data control systems, considerable in-house effort has been devoted to developing this capability. In the systems area, a significant in-house accomplishment has been the development of a general theory for mathematically simulating the coupling of thermal loads into the system dynamics.

A two-phase contract was awarded to Boeing Aerospace Co. in June 1979, for the development of an operational integrated analysis capability. The Phase I effort (10 months performance period) is to produce a detailed development plan and a pilot analysis program designed to demonstrate proof of concept. The Phase II effort is to produce the actual operational software system.

INTERACTIVE ANALYSIS PROGRAM ACTIVITY

IN-HOUSE (GSFC) ACTIVITY

- o THERMAL
  - o EVALUATE SUITABILITY OF NASTRAN VS. SINDA VS. SPAR
  - o ASSESS PRACTICAL LIMITS ON USE OF MODAL SOLUTION TECHNIQUE
- o STRUCTURES
  - o EVALUATE NASTRAN VS. SPAR VS. SAP-VI
- o CONTROLS
  - o DEVELOP LINEARIZATION TECHNIQUE FOR SAMPLED DATA CONTROL SYSTEMS
- o SYSTEMS
  - o DEVELOP GENERAL THEORY FOR COUPLING THERMAL LOADS INTO SYSTEM DYNAMICS

CONTRACTOR ACTIVITY

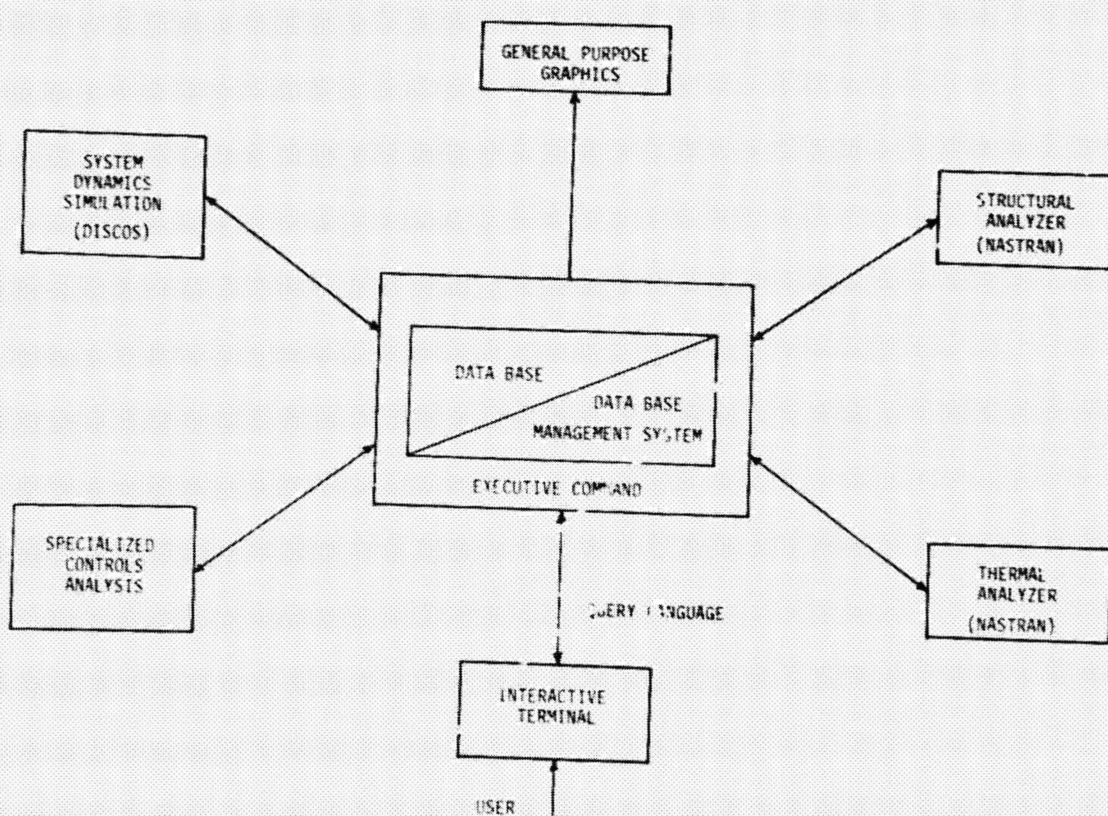
- o TWO PHASE EFFORT WITH END PRODUCT TO BE AN OPERATIONAL INTEGRATED ANALYSIS CAPABILITY
- o PHASE I AWARDED TO BOEING AEROSPACE CO. JUNE 79, (10 MONTHS PROGRAM)

CONCEPT OF IAC ARCHITECTURE

In a simplified fashion, the current concept of the IAC system architecture can be represented by the block diagram shown below. As stated earlier, the system is to be highly user oriented and have very efficient interdisciplinary data flow properties. The keys to making this possible are a powerful, yet flexible, data base management system and a highly user oriented executive command/query language and interactive graphics. Not only must the system perform the engineering calculations via the application programs but it must also be designed to efficiently manage, control, and manipulate all the data, input or generated, from the most primitive level to the highest level. This system by itself cannot miraculously solve all the human factor problems associated with interdisciplinary communication and data exchange. The goal is to produce a logical framework that will make this communication much less painful and actually give the practitioners an incentive to interrelate more directly.

The specific application programs shown in the diagram in parentheses are mainly for example purposes only. Final selection will not occur until after start of the Phase II activity.

CONCEPT OF IAC ARCHITECTURE



DEVELOPMENT OF SYSTEM DYNAMICS ANALYSIS METHODS

H. P. Frisch

DISCOS PROGRAM IMPROVEMENT ACTIVITY

As shown earlier in the IAC system concept block diagram, DISCOS is designated as a candidate application program to perform the system dynamics analytical simulation. DISCOS basically derives and sets up the computer code necessary to define the plant equations. The user, via FORTRAN code, defines all non-gyroscopic control and environmental loads on the system. DISCOS is structured so as to provide the user with a clean interface between the plant, the controller, and the environment. This clean interface, along with several special interface subroutines, help to minimize the problem associated with non-gyroscopic load definition.

DISCOS PROGRAM IMPROVEMENT ACTIVITY

DYNAMIC INTERACTION SIMULATION OF CONTROLS AND STRUCTURE

MOTIVATION: THE KEY TO BUILDING USEFUL SIMULATION MODELS IS TO MAKE THEM AS SIMPLE AS POSSIBLE. EXCESS DETAIL TENDS TO CONFUSE RATHER THAN CLARIFY.

NEED: A CAPABILITY TO RAPIDLY AND RELIABLY SET UP THE UNABRIDGED EQUATIONS OF MOTION FOR IDEALIZED SPACECRAFT SIMULATION MODELS.

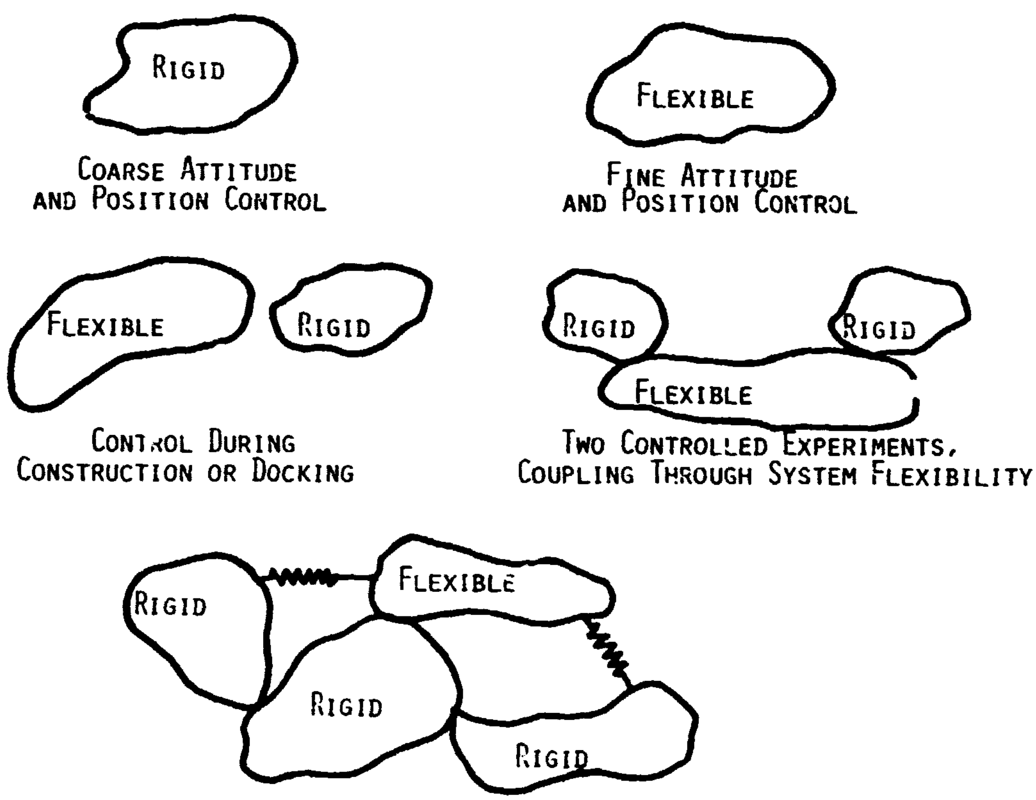
SIMULATION MODELS: FOR CONTROLS RELATED STUDIES SPACECRAFT CAN NORMALLY BE MODELLED AS A SYSTEM OF COUPLED RIGID AND FLEXIBLE BODIES.

DISCOS PROGRAM IMPROVEMENT ACTIVITY

Obviously a full DISCOS capability should not be used for the single rigid or a single flexible body model.

Coupled body problems conceptually look very simple and in most cases they are reasonably easy to understand; however, the derivation and computer implementation of the complete set of coupled non-linear equations of motion, accounting for all gyroscopic effects, can be extremely difficult to obtain and debug.

The DISCOS user need worry only about correctly setting up the input deck to define the problem. The equation derivation and computer implementation portion of the problem has already been taken care of by DISCOS.



DEPLOYMENT AND SHAPE CONTROL

USE DISCOS--TO AUTOMATICALLY DERIVE AND NUMERICALLY SOLVE THE EQUATIONS OF MOTION FOR THE CONTROLLED COUPLED BODY SYSTEM

DISCOS PROGRAM IMPROVEMENT ACTIVITY

Simulation models are structured with a dual purpose in mind:

1) Expose potential problem areas

2) Provide the engineer with sufficient insight into the problem so that a "fix" can be implemented

Excess detail usually will not hinder the exposure of a problem; however it usually will mask the true cause of the problem.

Coupled rigid-flexible body models, using a minimal number of flexible body modes, are usually adequate for most controls/structure interaction problems.

DISCOS

MODELLING CAPABILITY

- ARBITRARY NUMBER OF BODIES
- ANY OR ALL MAY BE FLEXIBLE
- RELATIVE DEGREES OF FREEDOM MAY BE
  - --KINEMATICALLY FREE
  - --KINEMATICALLY FIXED
  - --CONSTRAINED BY SPRINGS DAMPERS AND/OR MOTORS
  - --DEFINED BY AN APRIORI FUNCTION OF TIME
- TOPOLOGICAL LOOPS ALLOWED
- ARBITRARY CONTROL SYSTEM ALLOWED
- ENVIRONMENTAL LOADS ALLOWED
- FORCES AND TORQUES MAY BE APPLIED ANYWHERE
  - --DISCRETE LOADS ALLOWED
  - --DISTRIBUTED LOADS ALLOWED

DISCOS PROGRAM IMPROVEMENT ACTIVITY

As presently structured the controller can be defined by an arbitrary set of non-linear logical, algebraic and ordinary differential equations. The linearization procedure is numerical and will not work correctly if the equations cannot be linearized in the continuous time domain. Special techniques, under development, are required for the linearization of sampled data control equations.

DISCOS

ANALYSIS CAPABILITY

- COMPLETE NON-LINEAR TIME DOMAIN SIMULATION
- NUMERICALLY LINEARIZE EQUATIONS OF MOTION

  $\dot{X} = \underline{A}X$

  --IF CONTROLLER IS CONTINUOUS (ANALOG)– PLANT + CONTROL EQUATIONS LINEARIZED

  --IF CONTROLLER IS SAMPLED DATA SYSTEM - ONLY PLANT EQUATIONS LINEARIZED
- FREQUENCY DOMAIN ANALYSIS CAPABILITY

  IF CONTROLLER CONTINUOUS THEN FOR ANY DESIRED SENSOR-ACTUATOR RATIO

  --OPEN LOOP TRANSFER FUNCTIONS SET UP

  --CLOSED LOOP TRANSFER FUNCTIONS SET UP

  --QUASI-OPEN LOOP TRANSFER FUNCTIONS SET UP

  ANALYZED BY

  --BODE

  --NICHOLOS

  --NYQUIST

  --ROOT LOCUS

DISCOS PROGRAM IMPROVEMENT ACTIVITY

Eigenanalysis numerical methods have advanced significantly in the past 5 years. These advances have been incorporated to gain an added measure of numerical error control in the frequency domain analysis section of DISCOS.

Control/structure interaction analysis during orbit adjust requires motion to be measured relative to an acceleration reference to avoid numerical problems.

Last 3 items go together. This capability is essential for docking and appendage deployment problems. It is extremely difficult to implement since proper implementation requires information about the future before it can be computed. The new integration method provides a second order estimate of this future data halfway through the full integration cycle. This permits the proper set up of latching/unlatching logic. The need to conserve momentum during latch/unlatch leads to the last item. Numerical changes in momentum are error; if viewed as a known impulse it can be cancelled by applying an equal and opposite effect.

DISCOS

CAPABILITIES IMPLEMENTED FY79

- NEW STATE-OF-THE-ART NUMERICAL METHODS INCORPORATED IN FREQUENCY DOMAIN ANALYSIS SECTION
- MOTION NOW COMPUTABLE RELATIVE TO AN ACCELERATING FRAME OF REFERENCE
- DEGREES OF FREEDOM MAY BE LATCHED AND UNLATCHED DURING SIMULATION
- NEW INTEGRATION ROUTINE DEVELOPED TO ACCOMMODATE LATCHING/UNLATCHING NEEDS
- ADDITIONAL COMPUTATIONAL ERROR CONTROL LOGIC DEVELOPED FOR COMPUTATION OF GYROSCOPIC CROSS COUPLING EFFECTS

NEW SAMPLED DATA CONTROL ANALYSIS METHOD

Non-linear time domain analysis of a plant subject to a sampled data control can normally be handled without approaching insurmountable numerical or theoretical problems.

The real problems are associated with attempting to perform a frequency domain stability analysis. Current techniques that are known rapidly become computationally impractical, or theoretically deficient, as one is forced to incorporate multi-rate sampling, many zero order holds of different time duration and several different digital delays.

NEW SAMPLED DATA CONTROL ANALYSIS METHOD

PROBLEM: ZERO ORDER HOLDS AND DIGITAL DELAYS ARE NON-LINEAR ELEMENTS IN THE CONTINUOUS TIME DOMAIN. USUALLY THESE CANNOT BE READILY LINEARIZED

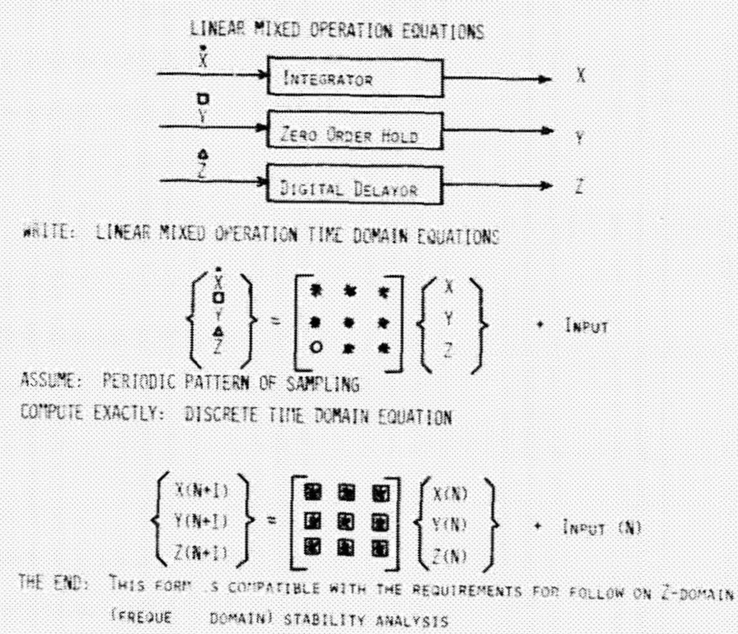
SOLUTION: DEVELOP AN ANALYSIS METHOD WHICH VIEWS THEM AS LINEAR ELEMENTS

METHOD: INTRODUCE THE CONCEPT OF A SET OF LINEAR MIXED OPERATION EQUATIONS

NEW SAMPLED DATA CONTROL ANALYSIS METHOD

Presented here is only the fundamental essence of the method. We first must view the meaning of the dot in the topmost figure. The dot simply says that given an initial state for X and a definition of the function X, then if the mathematical rules of integration are used, the value of X can be obtained for any future time. We now view the use of box in the next figure in the same manner. The box simply says that given an initial state for Y and a definition of the function Y, then if the mathematical rules for zero order hold are used, the value of Y can be obtained for any future time. An analogous statement follows for the use of triangle in the last figure. It is claimed that any linear sampled data control system can be expressed as a set of linear mixed operation equations as shown. Specifically note the zero in the 3,1 slot. Delay of a continuous signal is prohibited. We view the associated computational cost as not being worth the effort.

Next, a periodic pattern of sampling must be assumed. Without this assumption linear stability analysis is not possible. From this point on, the computer takes over to compute the elements of the coefficient matrix associated with the linear finite difference equation shown. This is done by a direct implementation of the mathematical rules of integration, zero order hold and delay. The period implied is that of the periodic pattern of sampling. This is, in effect, the end of the new method since this equation format is compatible with standard Z-domain (frequency domain) stability analysis methods.



NEW ANALYSIS METHOD FOR THERMALLY INDUCED MOTION

If finite element methods are used to define flexibility, then eventually one arrives at the equation shown and an associated set of vibration modes and natural frequencies. If either finite element or finite difference methods are used for linear thermal analysis then eventually one arrives at the thermal equation shown. This too is amenable to eigenanalysis methods and a set of thermal modes and natural thermal decay time constants can be obtained. Thermal modes define temperature patterns just as vibration modes define displacement shapes. Natural thermal decay time constants define how quickly a temperature pattern would decay to a mean value if the system was placed in a block box, just as natural frequencies define the vibration frequency associated with a particular vibration mode.

The trick to solving the thermally induced motion equation shown is to compute a thermally deformed shape associated with each thermal mode pattern and then to express each of these shapes as linear functions of the vibration modes. From this point more or less standard methods for arriving at generalized displacement and thermal coordinate equations via orthogonality relations are used. The resultant equations blend perfectly with the DISCOS program capabilities. A detail definition of the theory is scheduled for publication in the AIAA Journal of Guidance and Control January-February 1980. The title of the paper is "Thermally Induced Response of Flexible Structures, a Method for Analysis."

NEW ANALYSIS METHOD FOR THERMALLY INDUCED MOTION

BASIC CONCEPTS USED:

- STRUCTURES

  $M\ddot{X} + KX = 0$ — VIBRATION MODES, NATURAL FREQUENCIES

- THERMAL

  $C\dot{T} + DT = 0$ — THERMAL MODES, THERMAL DECAY TIME CONSTANTS

- THERMALLY INDUCED MOTION

  $M\ddot{X} + K(X-X_T) = 0$

  X_T = INSTANTANEOUS POSITION OF THERMAL EQUILIBRIUM

- SOLVED VIA USE OF VIBRATION AND THERMAL MODES

- EQUATIONS THAT DEFINE X_T VIEWED AS CONTROL EQUATIONS TO BLEND WITH DISCOS CAPABILITY

- PAPER TO BE PUBLISHED IN THE JANUARY-FEBRUARY 1980 ISSUE OF THE AIAA JOURNAL OF GUIDANCE AND CONTROL

EVALUATION OF CANDIDATE ANALYSIS CODES

G. K. Jones

ACCOMPLISHMENTS FY79

A VAX 11/780 version of SPAR was developed using as its basis the NASA PRIME version of SPAR. The major tasks were the development of new I/O routines for use with the VAX 11/780 computer and to restructure the code to make it compatible with the VAX data formats. The resulting code is all FORTRAN and makes maximum use of VAX virtual memory system to speed I/O operations.

Four dynamics analyses problems have been defined and three of these problems have been executed on both SPAR and NASTRAN (MSC 52 on VAX). The problems consisted of finding the free-free modes of various size space frame platform models. This class of structure (platform) was selected based on a review of potential LSST structural systems. Modal analyses was selected based on the fact that being able to define the structural modes is essential to the performance of coupled controls-structure analyses. Based on these analyses preliminary observations have been reached as to the relative merits of SPAR and NASTRAN.

LSST TECHNICAL REVIEW
INTERACTIVE ANALYSIS PROGRAM

ACCOMPLISHMENTS FY79

- o VAX 11/780 VERSION OF SPAR DEVELOPED
- o FOUR MODAL ANALYSES PROBLEMS DEFINED
- o THREE OF FOUR PROBLEM EXECUTED ON VAX USING SPAR AND NASTRAN (MSC-52)
- o PRELIMINARY OBSERVATIONS

CANDIDATE STRUCTURAL ANALYSIS CODES

The NASTRAN, SPAR, and SAP VI analysis codes were selected as candidates due to their use within NASA and or the aerospace community. Both NASTRAN and SPAR codes are available through COSMIC and commerical variants of all three codes exist. The NASTRAN program was originally developed by NASA and is a very complex (~300,000 lines of code), but versatile code. It is the most widely used structural analysis code. The other codes SPAR and SAP VI are less complex (~40,000 lines of code) and are not as widely used as NASTRAN. But since they were developed after NASTRAN they incorporate more advanced features in certain areas.

The three codes suitability for use in an interdisciplinary analysis system is being investigated. Of particular concern is how well each codes' would function in an integrated interdisciplinary analysis system. Other factors being assessed are the codes' ability to handle large problem dynamics analyses, their ease of usage, and their documentation.

LSST TECHNICAL REVIEW
INTERACTIVE ANALYSIS PROGRAM

CANDIDATE STRUCTURAL ANALYSIS CODES

CODES:

1. NASTRAN
2. SPAR
3. SAP VI

COMPARISON FACTORS:

o SUITABILITY FOR USE IN INTERDISCIPLINARY ANALYSIS SYSTEM

o LARGE PROBLEM ANALYSIS

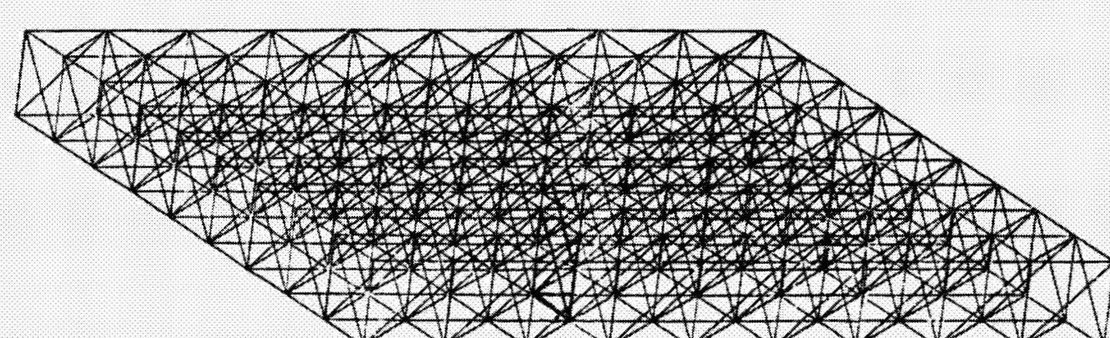
o EASE OF USAGE

o DOCUMENTATION

MODEL C

Four platform models were developed (Models A through D), progressively increasing in size. The smallest model had 8 grid points and the largest model had 300 grid points. Model C is the next to the largest and consists of 200 grid points and about 800 elements. It represents a 500 feet by 500 feet square space frame platform with a thickness of 50 feet. The other models differ from MODEL C only in complexity. The SPAR models were generated using the mesh generators in SPAR; the NASTRAN models were generated using the MOVE preprocessor program.

LSST TECHNICAL REVIEW
INTERACTIVE ANALYSIS PROGRAM



LSST PLATFORM-MODEL C

SPAR-NASTRAN PERFORMANCE

The analysis problems consisted of computing the first 10 to 12 free-free modes of the various platform models. Results for the three smaller models have been obtained. The SPAR run times were about the same as that for NASTRAN when the GIVENS-QR eigenvalue technique was selected in NASTRAN. The INVERSE method in NASTRAN ran substantially slower than the other methods. SPAR appears to use less physical memory than NASTRAN but further investigation is needed to confirm this fact. The input to the SPAR program was much more compact than the NASTRAN input. The NASTRAN rigid format feature is easy to use but lacks the flexibility of the SPAR command language which is also easy to use.

LSST TECHNICAL REVIEW
INTERACTIVE ANALYSIS PROGRAM

SPAR-NASTRAN PERFORMANCE

		SPAR		NASTRAN	
MODEL	DOF	CPU TIME (MIN)	MEMORY (BYTES)	CPU TIME (MIN)	MEMORY (BYTES)
A	48	0.57	100K	1.12(I)	200K
B	108	1.20	124K	2.93(I) 1.03(G)	250K
C	1200	21.2	175K	38.9(I) 21.8(G)	750K 300K

I=INVERSE

G=GIVENS-QR

PRELIMINARY OBSERVATIONS

One tentative conclusion based on the work performed to date is that for modal analysis the performance of SPAR (VAX version) and MSC52 NASTRAN are comparable. SPAR's strong points are that it is easy to use, has compact input, has a built in data base and a simple program structure. This last point is important in that it means that new features can be added to SPAR much more easily than to NASTRAN. The SPAR weak points are its poor documentation, no MPC capability and only one eigenvalue method. In addition the SPAR eigenvalue method was found to be very sensitive to the value of shift parameter selected. More than one run was usually required to find the desired eigenvalues. NASTRAN's strong points are its documentation, MPC capability and its reduction technique. The problem with NASTRAN is that it is a complex code that is difficult to modify and requires a large amount of input. NASTRAN (MSC-52) has two useful eigenvalue techniques (GIVENS-QR, INVERSE) but they are not without their problems either. The GIVENS-QR method when coupled with an appropriate reduction is fast but sometimes has trouble getting good rigid body modes. The INVERSE method exhibits a set of problems similar to the SPAR technique.

LSST TECHNICAL REVIEW
INTERACTIVE ANALYSIS PROGRAM

PRELIMINARY OBSERVATIONS

- o SPAR-NASTRAN HAVE ABOUT SAME SOLUTION SPEED PERFORMANCE
- o WEAK POINTS

  SPAR--DOCUMENTATION, EIGENVALUE, LACK OF MPC OR REDUCTION TECHNIQUE

  NASTRAN--COMPLEX INPUT, COMPLEX CODE, DATA BASE
- o STRONG POINTS

  SPAR--DATA BASE, EASY TO USE, COMPACT INPUT, COMPACT CODE

  NASTRAN--DOCUMENTATION, MPC, REDUCTION TECHNIQUE

THERMAL ANALYSIS COMPUTER CODE ACTIVITY

The SINDA program represents the leading candidate of the "traditional" finite difference type thermal analyzers, whereas NASTRAN and SPAR are of the finite element variety. A comparative evaluation is to be made to accurately document the relative performance capabilities and suitability for incorporation into an integrated analysis environment. The CAVE-3 program, developed by Grumman Aerospace Co. for LaRC, is the only known aerospace oriented program designed to perform thermal analyses via the modal solution method. This program is to be utilized to solve a number of demonstration problems to assess what limitations and usage criteria can be expected when using a modal solution approach.

THERMAL ANALYSIS COMPUTER CODE ACTIVITY

- NASTRAN (MSC-52) INSTALLED ON VAX 11/780, DEMONSTRATION PROBLEMS RUN
- SINDA INSTALLED ON VAX 11/780, DEMONSTRATION PROBLEMS RUN
- SPAR THERMAL ANALYZER PROCESSORS CONVERTED AND INSTALLED ON VAX 11/780
- CAVE-3 MODAL SOLUTION BASED ANALYZER INDENTIFIED AND OBTAINED FROM GAC, INSTALLED ON IBM 360/91, DEMONSTRATION PROBLEMS RUN

DEVELOPMENT OF INTEGRATED ANALYSIS CAPABILITY SYSTEM

W. J. Walker

PROGRAM STATUS

The Integrated Analysis Capability for Large Space Systems is funded under Contract NAS5-25767 by the Goddard Space Flight Center. Mr. J. P. Young of GSFC is the Contract Technical Officer. The current contract is for Phase I of a two-phase effort with Phase II being a pre-negotiated option exercisable by GSFC. Phase I started on June 28, 1979 and continues for a 10-month period. The Statement of Work for Phase I specifies two tasks. The first is to develop a detailed plan for the Integrated Analysis Capability (IAC) computer code. The intent is then to implement this development plan during Phase II. This plan will identify the technical modules to be used with the IAC, its database system and its interactive capability. In addition, a pilot analysis code will be utilized to demonstrate the concepts planned for the IAC. All computer work during Phase I of this effort will be done on the DEC VAX 11/780 machine and use Tektronix's graphics hardware.

Program Status

Contract NAS5-25767

Starting date: June 28, 1979

Duration of phase I: 10 months

Phase I:

Task 1–Generate a detailed development plan for the IAC

Task 2–Produce a simplified pilot analysis code

IAC - CAPABLE OF PERFORMING

The IAC has as its goal the capability of performing the indicated analyses for the conceptual/preliminary design of large space structures. The statements shown describe the necessary technical data flow between the disciplines planned for the IAC; Thermal, Structural and Controls. By Structural is meant both the strength and vibratory considerations as well as the overall system dynamics behavior of a large space system. This capability involves implementing a number of individual computer modules and insuring the interdisciplinary data flow. Depending on the exact configuration of the structural system under study and its level of maturity the analysts can select the appropriate solution. It is felt that this IAC capability encompasses the major anticipated structural needs of the precision/shaped surface structures, low stiffness planar substructures and high stiffness truss structure contained within the large space structures mission model.

IAC–Capable of Performing

- Thermal/structural analysis in a standalone mode
- Thermal/structural coupled analysis in a sequential mode
- Structural/control system coupled analysis
- Quasi-static thermal/structural/control system coupled analysis
- Fully coupled thermal/structural/control system analysis

INTERACTIVE DATA HANDLING

The IAC will provide to the analyst an extensive capability to interactively investigate the behavior of LSS. This is envisioned as occurring within two classes of activity. First, the user interacting with the database in terms of updating existing models in the system and secondly, the user interacting with the data from previous analysis executions in either a query mode or a graphics mode of operations. This activity will involve both the database management system and the database per se. Also, the IAC system will provide an executive system to control the IAC modules and to interact with each module during execution as is necessary. The software development planned for the IAC Interactive Capability must necessarily consider the hardware system. Currently, the computer interactive terminal technology is rapidly changing with vendors developing new products annually. Due to this state of affairs the decision with respect to which interactive terminal hardware systems to use will be postponed as long as possible. For the pilot code, however, Tektronix terminals will be utilized. All graphics software developed for the IAC program will conform to the 1979 SIGGRAPH standards.

Interactive Data Handling

- User/database interface
- User/module interface
- Graphics hardware: Tektronix
- Graphics software: Conform to 1979 SIGGRAPH standards

DATABASE SYSTEM

The database system planned for the IAC will be a relational database system. The organization of this database system is defined by what is known as a two-schema model: logical and physical. The logical organization represents the user's view of the database and will provide security, reliability and relational capability of the system. This organization will establish logical partitions and allow for transfer of data between the partitions, define the organization within a partition and implement the relationships among the data. The physical organization represents the machine implementation of the database and will establish physical segments, records, etc. Among the system's characteristics which will be particularly important from the user's viewpoint will be the permanent nature of the database storage as well as its capability to support multiple users concurrently. The IAC will use a single central processing unit (CPU) and not consider a distributed processing system such as being developed for the IPAD system. The IAC is intended to provide back-up capability and allow recovery in case of computer failure. In addition, a data definition language (DDL) will allow user specification for details of the database schema. Finally, a user oriented query language will provide the interactive access to the database.

Database System

- Two-schema organization
  - Logical
  - Physical
- Characteristics:
  - Multiuser (concurrent usage)
  - Single CPU
  - Recovery
  - Backup
- Data definition/query language

INTEGRATED ANALYSIS CAPABILITY
PILOT PROGRAM

The IAC will have specific modules associated with the structural, thermal, system dynamics and controls technical disciplines shown below on the left. At the present time the specific modules to be used during Phase II have not been selected. For the Phase I pilot code, the technical modules shown below on the right will be used. The NASTRAN thermal and structural analysis will be used in conjunction with the DISCOS program for system dynamics. The DISCOS controls subroutine will be used for purposes of the pilot program. For Phase II a relational database system will be developed for the IAC in conjunction with an interactive tutorial and query capability as well as extensive use of graphics. The pilot program will employ a file oriented database system to demonstrate the interdisciplinary data flow and the user oriented query language. Interactive terminals will also be used along with the pilot program to demonstrate the executive system approach and the interactive graphics. For the graphics output it is planned to use a user oriented menu approach. It should be noted that the pilot program capability will be used to solve a selected demonstration problem. This problem was chosen at the Initial Program Review and is described below.

Integrated Analysis Capability
Pilot Program

- **Structural:** **NASTRAN**
- **Thermal:** **NASTRAN**
- **System dynamics:** **DISCOS**
- **Controls:** **DISCOS**
- **Database system**
- **Interactive data handling**

PILOT PROGRAM

The function of the pilot program is to provide proof of concept evidence for the IAC system through the execution of a demonstration problem. Thus the pilot program is a restricted subset of the full IAC system capability. The primary software characteristics of this program are shown below. It was specified by the contract that the pilot program be developed for operation on the DEC VAX computer. Boeing Aerospace has a VAX machine at its Kent Space Center and we have remote access to this machine using a Tektronix 4014 from our work area. For the pilot program as discussed previously, a file oriented database system will be utilized to interface the technical modules of NASTRAN and DISCOS and provide a data repository for the user. This system will be accessed interactively to demonstrate the planned capability of the IAC and the IAC/user environment. The graphics capability will use the Tektronix developed Plot 10 package operational on the VAX. This capability will be demonstrated by plotting DISCOS output data. The executive system approach for both the analysis modules and database system will be incorporated into the pilot program.

Pilot Program

- Operational on DEC VAX 11/780
- File-oriented database system
- Interactive graphics
- Executive system–module/data manager

DEMONSTRATION PROBLEM

The demonstration problem selected for the pilot code is a thirty (30) meter antenna structure. This structure has the primary structural elements: spacecraft bus, reflector, and feed truss. A previously developed NASTRAN model of this structure was provided to us by the Jet Propulsion Laboratory (JPL). This model has been exercised generating mode shapes and frequencies for comparison with JPL data (which was excellent). It is planned to perform two types of analysis with this model. One a thermal/structural analysis and the second a structural/control analysis. These analyses will follow the second and third analysis capability shown on the page titled "IAC-Capable of Performing." One purpose of this solution is to demonstrate the user control of the executive system to initiate the thermal and structural analysis. Another is to demonstrate the ability of the system to identify and transfer module generated output to the database and extract data from the database as input to another module. The second analysis performs a similar function but will involve the DISCOS-Controls subroutine and the interactive graphics plotting capability. For this analysis the antenna will be assumed to be gimbaled at the spacecraft bus and one degree of freedom control exercised.

Demonstration Problem

- **30-metre antenna**
  - **Bus**
  - **Reflector**
  - **Feed**
- **Solve two problem types:**
  - **Thermal/structural analysis**
  - **Structural/control analysis**